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DIFFERENCE IN THE HEATING RATE OF THE EASTERN AND WESTERN LIMBS OF THE MOON AFTER AN ECLIPSE

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3a. DIFFERENCE IN THE HEATING RATE OF THE EAST~~ERN~~ AND WEST~~ERN~~ LIMB~~S~~ OF THE MOON AFTER AN ECLIPSE

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SUMMARY

A difference in the heating rate of the esatern and western limbs of the Moon was revealed during the lunar eclipse of 7 July 1963. One of the probable causes of the observed effect is the difference of temperature gradients of the surface layers of Moon's eastern and western limbs during full moon. On this assumption, the value of γ for the upper decimeter layer is estimated to be $\gamma = (k\rho c)^{-1/2} \approx 600 \div 900$.

* * *

The observations of Moon's thermal emission in the 8 – 14 mk region of the spectrum [1], conducted during the eclipse of 7 July 1963, have shown that upon egress from shadow the Moon's surface is heated at a different rate on the eastern and western limbs. Scanning of the Moon was conducted uninterruptedly from west to east along four plans, passing through the Aristarchus crater (1st plan), Mare Crisium (2nd plan), Mare Humorum and Mare Necteris (3rd plan), Longomontanus ring formation and Fernelius crater (4th plan).

The variation of the measured thermal flux from Moon areas of 100 x 60 km dimension with the increase of illuminance Φ (Φ being the area illuminance, referred to that of full moon), is brought out in Fig. 1.

3b. (RAZLICHIYE SKCROSTI NAGREVANIYA VOSTOCHNOGO I ZAPADNOGO KRAYEV LUNY POSLE ZATMENIYA)

From the viewpoint of details of Moon's relief, these areas were selected at random. Three graphs correspond to areas disposed at distances from the center of the disk : $r = 0.96\, R_{☽}\; 0.93\, R_{☽}\quad 0.45\, R_{☽}$. The scale of temperatures computed by measured intensities, taking into account the atmosphere transparence, telescope's and device's geometry and in the assumption that the surface of the Moon emits as a blackbody, is plotted in ordinates.

The difference between the heating rate of the western and eastern limbs is seen well for great distances from disk's center $(r = 0{,}80 - 0{,}99\, R_{☽})$. However, the differences are fully concealed by point scattering already at distance $r = 0{,}5\, R_{☽}$ (mainly on account of interferences from measuring devices). It is clear, that this difference is linked with the previous history of the areas, situated on the western and eastern limbs: the western limb of the Moon was sunlit during about two weeks prior to observation, while the terminator passed through the eastern limb only recently. The course of the curves for the eastern limb reveals a certain lag in temperature rise at initial stages of heating. Such lag can be caused by the fact that at the eastern limb, the energy, outgoing in the depth of the surface because of conductance, is greater than at the western limb, for in the first case the temperature gradients in the superficial layer of the ground are greater.

Generally speaking, the delayed temperature rise at continuous energy input from the Sun may be also caused by phase transition type processes or by variations of the state of Moon's superficial layer substance (for example, the sintering or the agglomeration of dust particles under the effect of heating, the fusion of the formation ouside or under the superficial layer, etc.).

At present we lack the possibility of separating these two effects. But if the thermal inertia gives a great contribution, we may attempt to determine the parameter $\gamma = (k\rho c)^{-1/2}$ directly from the detected retardation of the heating effect; here **k** is the conductance, ρ is the density and <u>c</u> is the specific heat capacity. Strictly speaking, computations of thermal regime must be conducted at specific parameter of lunar soil. Comparison of the retardation, calculated from the solution of the heat conductivity equation for various γ , with that measured experimantally, provides the means of determining γ. In the case when it should appear that there is generally no possibility of obtaining a dependence, coinciding with the experimental one for the same parameter, the assumption of main role of heat conductivity in the effect detected will not, apparently, correspond to reality. The precise computations are quite cumbersome; they require the use of computers and that is why, so far, they failed to materialize with us. As a first step, we conducted only the estimate of the value of the parameter γ, utilizing the values of temperature gradients in the superficial layer, obtained from the computation and experimental data by lengths of penetration into the lunar soil of the radiation with various wavelengths within the radioband.

To carry out the estimate, it is practical to assign oneself identical temperatures for the portions of eastern T_E and western T_W edges ($T_E = T_W$), which are established for various illuminances Φ_E and Φ_W. The horizontal lines in Fig. 1 cross the heating curves of the eastern and western limbs at points, the abscissa of which correspond to various values of Φ.

For the points of intersection we may write the conditions of energy balance as follows

$$A \cos \theta_{\text{эфф}} \Phi_E = \sigma T_E^4 + q_E, \tag{1}$$

$$A \cos \theta_{\text{эфф}} \Phi_W = \sigma T_W^4 + q_W, \tag{2}$$

where A is a solar constant, q_E and q_W are the fluxes through the surfaces of the eastern and western areas.

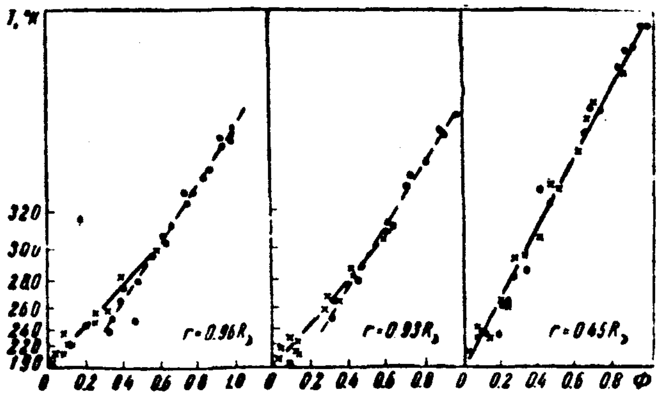

Fig. 1.- Dependence of the thermal flux and of temperature on the relative illuminance Φ in the penumbra after the end of the total phase of eclipse for various distances from the center of the disk.

The value of $\cos\theta_{эфф}$ has the following sense. For a smooth Moon the illuminance of the area situated at disk's limb is equal to A cos θ, where θ is the angle between the normal to that surface and the direction of solar ray incidence. However, the roughness of the Moon's surface leads to the dependence of thermal emission intensity on the angle θ not being subject to the law of the cosine. According to our measurements, this dependence has the form shown in Fig. 2. The great intensity of thermal radiation by disk's limbs, compared to cos θ is linked with the roughness, and, consequently with the increase of illumination on account of the presence of surface elements with a smaller angle θ, that is, somehow with an increase of cos θ. That is why

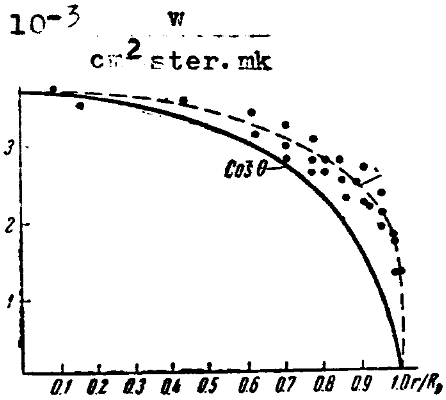

Fig. 2. - Distribution of thermal along the Moon's disk at full moon.

$$\cos\theta_{эфф} = \cos\theta\, I_{р}\theta / I_{гл}\theta,$$

where $I_{р}(\theta)$ is the flux from the real Moon and $I_{гл}\,\theta$ is the flux from a smooth Moon.

Subtracting from (1) (2), we shall obtain

$$A\cos\theta_{эфф}(\Phi_E - \Phi_W) = q_E - q_W,$$
$$q_E = k\left(\frac{\partial T}{\partial x}\right)_E, \quad q_W = k\left(\frac{\partial T}{\partial x}\right)_W. \qquad (3)$$

Utilizing the well known correlation of the penetration depth of the thermal wave $l_T = (2k/\rho c\omega)^{1/2}$, where k is the heat conductivity, c is the heat capacity, ρ is the density and ω the angular rotation frequency of the Moon, and also the correlation between the depths of penetration of thermal and electromagnetic waves $l_э = 2\lambda l_T$, obtained in [2], we shall obtain

$$q = 2(k\rho c)^{1/2}\cdot(2\omega)^{1/2}\partial T/\partial\lambda.$$

Substituting this expression in (3), we shall have

$$\gamma = (k\rho c)^{-1/2} = \frac{2(2\omega)^{1/2}\left[\left(\frac{\partial T}{\partial \lambda}\right)_W - \left(\frac{\partial T}{\partial \lambda}\right)_E\right]}{A \cos\theta_{\text{эфф}}(\Phi_W - \Phi_E)}. \tag{4}$$

The estimates of temperature gradients on the eastern and western limbs were realized as follows. In Fig. 3 we plotted by solid line the dependence of the measured radiotemperature T on wavelength for the points distant by $r = 0.96\, R_{☽}$ from the center to the eastern and western sides of Moon's disk at fullmoon. The dependence was plotted according to data of [2].

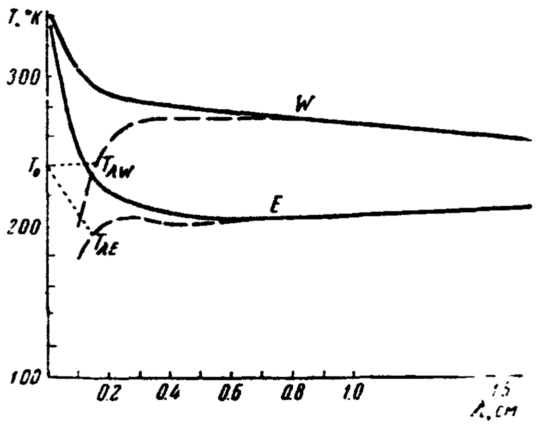

Fig. 3. - Dependence of the temperature on wavelength for the eastern and western limbs of the lunar disk in time of full moon

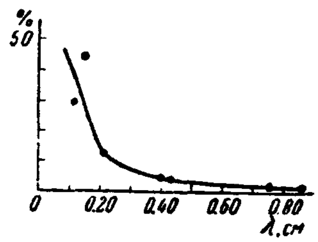

Fig. 4. - Maximum temperature drop (in percent, as a function of λ at time of the total phase of eclipse.

It is well known that any somewhat noticeable temperature variation during eclipse is observed for $\lambda < 0.4$ cm. Plotted in Fig. 4 is the dependence of mean radiotemperature drop along the disk in percent during the total phase of eclipse for various λ [3]. The dependence of the temperature on wavelength during the total phase (Fig. 3, dashes) was obtained from temperature distribution at full moon, taking into account the curve of Fig. 4. At the end of the total phase of the eclipse the surface, found to be in the penumbra, begins to be subject to heating under the action of the rising solar flux. Since the dependence of temperature on wavelength is available only for the total phase of eclipse (Fig. 3), its is desirable to make use of those experimental points of the curves in Fig. 1. which correspond to lowest temperatures. We utilized for the estimate the points corresponding to surface temperature $T_o = 240^o$ K. The value of $\partial T / \partial \lambda$ is determined from Fig. 3, as $(T_0 - T_\lambda) / \lambda$, where T_λ is taken by dashed curves for the eastern and western limb of the Moon. From Fig. 3, we may obtain that

$$(\partial T / \partial \lambda)_W - (\partial T / \partial \lambda)_E$$

has a maximum, equal to 300 deg/mm for $\lambda = 1.5$ mm. This value is utilized for the estimate. Taking A = 1.99 cal/cm min, $\omega = 2.51 \cdot 10^{-6}$ sec^{-1}, $\Phi_W - \Phi_E = 0.12$ (from Fig. 1), we obtain $(k\rho c)^{-1/2} = 600$. An analogous procedure for $0.93\, R_☽$ gives $(k\rho c)^{-1/2} = 900$.

Therefore, the values of γ, obtained as a result of rough estimate, are close to the values, determined by radioastronomical, as well as by optical methods [2]. This allows us to assume, that in the observed differences in the heating rate of the eastern and western limbs, a significant role is played by the heat conductivity of lunar soil.

***** THE END *****

Institute of Physics in the name of P. N. Lebedev of the USSR Academy of Sciences, and Astronomical Council of the USSR Academy of Sciences.

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